

Supporting Information for

“Noble gas mass-spectrometry for extraterrestrial micro-samples: analyses of asteroid matter returned by Hayabusa2 JAXA mission” by Alex Meshik^a, Olga Pravdivtseva^a, Ryuji Okazaki^b, Kasumi Yogata^c, Toru Yada^c, Fumio Kitajima^b, Hisayoshi Yurimoto^d, Tomoki Nakamura^e, Takaaki Noguchi^f, Hikaru Yabuta^g, Hiroshi Naraoka^b, Kanako Sakamoto^c, Shogo Tachibana^{ch}, Masahiro Nishimura^c, Aiko Nakato^c, Akiko Miyazaki^c, Masanao Abe^c, Tatsuaki Okada^c, Tomohiro Usui^c, Makoto Yoshikawa^c, Takanao Sakai^c, Satoshi Tanaka^c, Fuyuto Teruiⁱ, Satoru Nakazawa^c, Seiichiro Watanabe^j, Yuichi Tsuda^c and Hayabusa2 Initial Analysis Volatile Team

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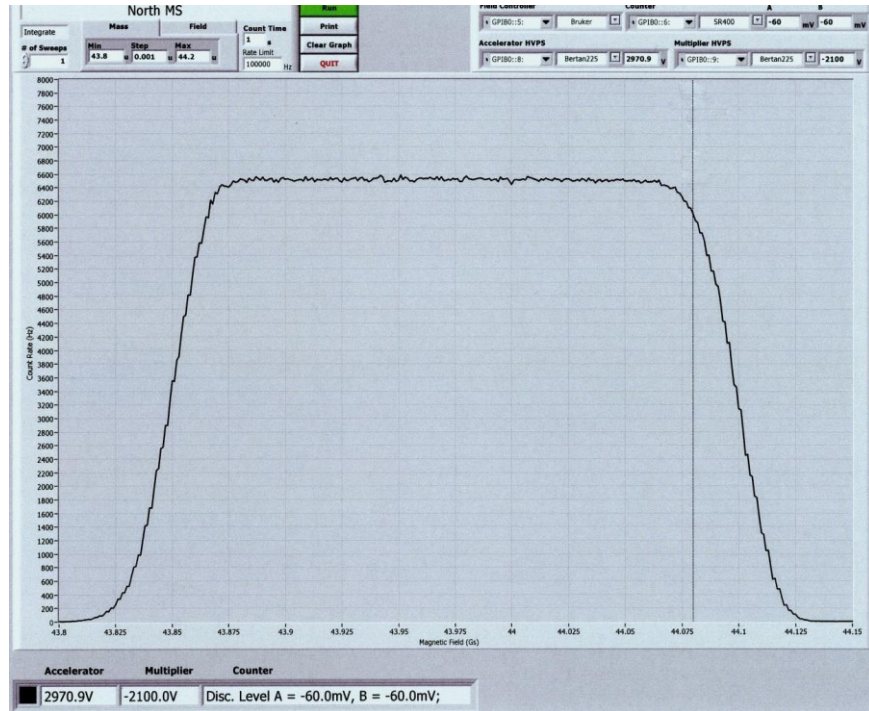


Fig. S1 Typical peak shape of the mass spectrometer with >95% ion transmission. Flat top of the peak ($m/e = 44$, count rate ~ 6500 counts/s) indicates that all ions pass through the detector slit.

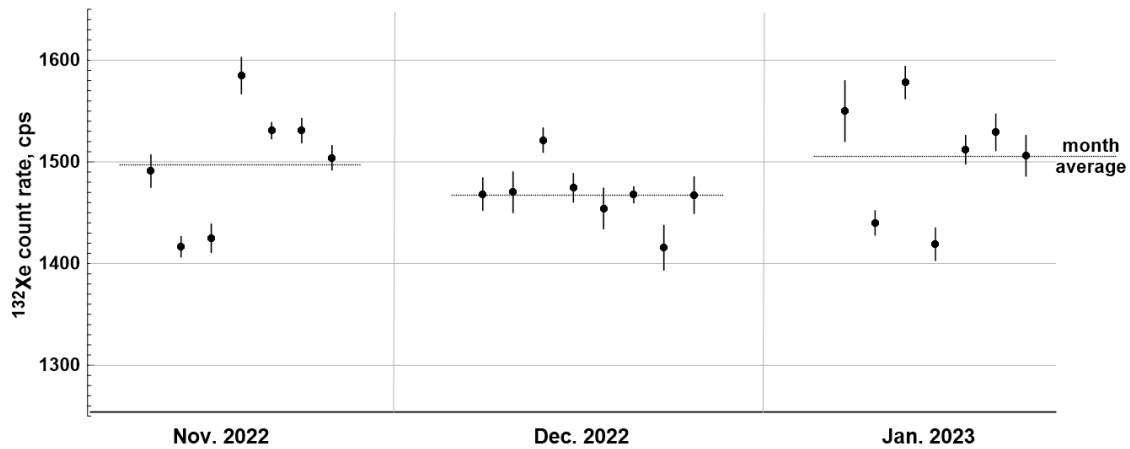


Fig. S2 Temporal variations of the ion count rate corresponding to standard amount of xenon admitted to the mass spectrometer. Absolute sensitivity variations do not exceed $\pm 7\%$.

C0106-05 (82 µg)

T, °C	⁴ He, E-04 cc/g	³ He/ ⁴ He × E-04	± (1σ)
340	0.0010	n.d.	n.d.
530	0.0997	7.20	3.80
870	0.9659	5.38	0.86
1260	0.8845	2.30	1.17
1500	0.0178	n.d.	n.d.
1610	0.0012	n.d.	n.d.
1770	0.0016	n.d.	n.d.
Total	1.9717	4.39	0.68

A0105-04 (173 µg)

T, °C	⁴ He, E-04 cc/g	³ He/ ⁴ He × E-04	± (1σ)
340	0.0009	n.d.	n.d.
530	0.0658	5.40	2.82
700	0.2308	5.90	0.47
870	0.4285	4.10	0.33
1000	0.3780	3.60	0.48
1130	0.0278	3.90	3.30
1260	0.0150	n.d.	n.d.
1400	0.0085	n.d.	n.d.
1500	0.0056	n.d.	n.d.
1610	0.0005	n.d.	n.d.
1770	0.0006	n.d.	n.d.
Total	1.1614	4.44	0.23

(n .d. – not determined)

Reference compositions

Component (ref.)	³ He/ ⁴ He × E-04	± (1σ)
Q (S1)	1.23	0.02
HL (S2)	<1.70	2.82
SW (S3)	4.64	0.009
Earth Atmosphere (S4)	0.01382	0.00005

C0106-05 (82 µg)

T, °C	²⁰ Ne E-6 cc/g	²¹ Ne/ ²² Ne	± (1σ)	²⁰ Ne/ ²² Ne	± (1σ)
340	0.0003	0.0104	0.0758	5.02	3.18
530	0.0394	0.1211	0.0892	7.57	8.35
870	0.6470	0.0902	0.0029	12.95	0.26
1260	0.3587	0.0690	0.0029	9.99	0.33
1500	0.0205	0.0632	0.0396	7.74	7.63
1610	0.0081	0.0133	0.0227	8.07	7.16
1770	0.0263	0.1759	0.1480	8.77	4.84
Total	1.1003	0.0832	0.0040	12.03	0.60

A0105-04 (173 µg)

T, °C	²⁰ Ne E-6 cc/g	²¹ Ne/ ²² Ne	± (1σ)	²⁰ Ne/ ²² Ne	± (1σ)
340	0.004	0.0160	0.0123	7.66	4.79
530	0.035	0.1625	0.0218	11.70	1.04
700	0.184	0.1546	0.0043	12.14	0.26
870	0.250	0.1039	0.0020	11.12	0.16
1000	0.122	0.0897	0.0026	10.26	0.25
1130	0.027	0.1108	0.0083	10.33	0.72
1260	0.018	0.0300	0.0052	8.22	1.27
1400	0.014	0.0175	0.0082	10.79	2.67
1500	0.014	0.0348	0.0127	10.95	2.72
1610	0.006	0.0264	0.0091	6.23	1.85
1770	0.014	0.0355	0.0077	10.21	2.45
Total	0.687	0.0107	0.0002	10.96	1.67

Reference Ne compositions

Component (ref.)	²¹ Ne/ ²² Ne	± (1σ)	²⁰ Ne/ ²² Ne	± (1σ)
Q (S1)	0.0294	0.0010	10.67	0.02
HL (S2)	0.1625	0.0218	8.500	0.057
G (S5)	< 0.0015		< 0.1	
SW (S6)	0.03361	0.00018	13.972	0.025
Earth atmosphere (S7)	0.0290	0.0003	9.80	0.08
GCR in chondrites (S8)	0.8 – 0.95		0.7 – 0.93	

C0106-05 (82 µg)

T, °C	³⁶ Ar, E-6 cc/g	³⁶ Ar/ ⁴⁰ Ar	± (1σ)	³⁸ Ar/ ⁴⁰ Ar	± (1σ)
340	0.032	0.00360	0.00005	0.00068	0.00002
530	0.126	0.00452	0.00002	0.00086	0.00001
870	0.310	0.01789	0.00010	0.00333	0.00004
1260	0.939	0.10417	0.00434	0.01917	0.00081
1500	0.505	0.05814	0.00203	0.01072	0.00038
1610	0.056	0.00377	0.00004	0.00071	0.00002
1770	0.058	0.00365	0.00003	0.00069	0.00001
Total	2.025	0.01976	0.00053	0.00366	0.00010

A0105-04 (173 µg)

T, °C	³⁶ Ar, E-6 cc/g	³⁶ Ar/ ⁴⁰ Ar	± (1σ)	³⁸ Ar/ ⁴⁰ Ar	± (1σ)
340	0.019	0.00367	0.00002	0.00069	0.00001
530	0.039	0.00471	0.00001	0.00086	0.00001
700	0.105	0.02347	0.00011	0.00431	0.00005
870	0.345	0.06024	0.00036	0.01117	0.00010
1000	0.398	0.06410	0.00041	0.01176	0.00010
1130	0.176	0.03891	0.00015	0.00714	0.00006
1260	0.209	0.04785	0.00023	0.00874	0.00007
1400	0.212	0.05618	0.00032	0.01028	0.00009
1500	0.100	0.06289	0.00040	0.01149	0.00011
1610	0.026	0.00419	0.00002	0.00079	0.00001
1770	0.007	0.00384	0.00009	0.00074	0.00002
Total	1.637	0.03137	0.00009	0.00577	0.00002

Reference compositions

Component (ref.)	³⁶ Ar/ ³⁸ Ar	± (1σ)	⁴⁰ Ar/ ³⁶ Ar	± (1σ)
Q (S1)	5.34	0.02		
HL (S2)	4.41	0.06		
SW (S6)	5.501	0.005	16.6	0.1
Cosmogenic (S8)	0.60 – 0.665			
Earth atmosphere (S9)	5.305	0.008	298.56	0.31

C0106-05 (82 µg)

T, °C	⁸⁴ Kr, E-08 cc/g	⁷⁸ Kr	± (1σ)	⁸⁰ Kr	± (1σ)	⁸² Kr	± (1σ)	⁸³ Kr	±1σ	⁸⁶ Kr	± (1σ)
340	0.08	0.0070	0.0025	0.0465	0.0023	0.198	0.011	0.206	0.002	0.3050	0.0077
530	0.90	0.0087	0.0006	0.0415	0.0012	0.205	0.004	0.201	0.002	0.3035	0.0023
870	0.37	0.0091	0.0004	0.0410	0.0009	0.204	0.001	0.200	0.002	0.2983	0.0057
1260	1.11	0.0081	0.0002	0.0391	0.0005	0.201	0.001	0.201	0.001	0.3123	0.0021
1500	0.58	0.0088	0.0005	0.0384	0.0017	0.203	0.002	0.202	0.003	0.3121	0.0029
1610	0.07	0.0124	0.0026	0.0349	0.0044	0.205	0.007	0.206	0.007	0.3071	0.0087
1770	0.06	0.0104	0.0021	0.0324	0.0062	0.195	0.005	0.197	0.005	0.3082	0.0063
Total	3.17	0.0086	0.0003	0.0398	0.0005	0.203	0.001	0.201	0.001	0.3077	0.0013

A0105-04 (173 µg)

340	0.13	0.0132	0.0012	0.0396	0.0033	0.207	0.003	0.206	0.004	0.3046	0.0090
530	0.37	0.0086	0.0007	0.0387	0.0017	0.201	0.004	0.198	0.004	0.3028	0.0061
700	0.14	0.0139	0.0005	0.0409	0.0011	0.202	0.002	0.204	0.002	0.3047	0.0044
870	0.29	0.0089	0.0007	0.0395	0.0011	0.206	0.004	0.205	0.002	0.3065	0.0025
1000	0.36	0.0092	0.0003	0.0398	0.0015	0.207	0.004	0.204	0.002	0.3119	0.0017
1130	0.24	0.0111	0.0008	0.0395	0.0019	0.202	0.005	0.201	0.003	0.3082	0.0073
1260	0.18	0.0101	0.0010	0.0390	0.0015	0.199	0.002	0.202	0.003	0.3114	0.0023
1400	0.26	0.0097	0.0006	0.0419	0.0087	0.204	0.006	0.202	0.005	0.3071	0.0033
1500	0.22	0.0107	0.0007	0.0418	0.0010	0.204	0.006	0.200	0.001	0.3087	0.0027
1610	0.02	0.0104	0.0031	0.0423	0.0068	0.200	0.011	0.203	0.002	0.3100	0.0097
1770	0.03	0.0155	0.0027	0.0414	0.0025	0.204	0.007	0.202	0.006	0.3056	0.0084
Total	2.24	0.0102	0.0002	0.0400	0.0005	0.2036	0.0001	0.2024	0.0010	0.3074	0.0016

Reference compositions

Component (reference)	⁷⁸ Kr	± (1σ)	⁸⁰ Kr	± (1σ)	⁸² Kr	± (1σ)	⁸³ Kr	± (1σ)	⁸⁶ Kr	± (1σ)
Q (S1)	0.00603	0.00003	0.03937	0.00007	0.2018	0.0002	0.2018	0.0002	0.3095	0.0005
HL (S2)	0.0042	0.0010	0.0305	0.0010	0.1590		0.1989	0.0010	0.3623	0.0018
G (S5)			0.0133 – 0.0183		0.4167		0.1192 – 0.0054		0.454 – 1.176	
N (S5)			0.03962	0.00040	0.2028	0.0021	0.2018	0.0032	0.2842	0.0036
SW (S6)	0.00642	0.00005	0.0412	0.0002	0.2054	0.0002	0.2034	0.0002	0.3012	0.0004
Earth atmosphere (S10)	0.006087	0.0020	0.039599	0.000020	0.20217	0.00004	0.20136	0.00021	0.30524	0.00025
²³⁸ U fission (S11)							0.23	0.08	7.69	1.18
²⁴⁴ Pu fission (S11)							0.54	0.02	2.00	0.08

C0106-05 (82 µg)

T, °C	¹³² Xe, 10 ⁻⁸ cc/g	¹²⁴ Xe	± (1σ)	¹²⁶ Xe	± (1σ)	¹²⁸ Xe	± (1σ)	¹²⁹ Xe	± (1σ)	¹³⁰ Xe	± (1σ)	¹³¹ Xe	± (1σ)	¹³⁴ Xe	± (1σ)	¹³⁶ Xe	± (1σ)
340	0.063	0.00392	0.00051	0.00292	0.00052	0.0707	0.0062	0.976	0.018	0.1500	0.0052	0.782	0.018	0.3698	0.0194	0.3271	0.0065
530	0.983	0.00333	0.00016	0.00318	0.00019	0.0722	0.0009	1.029	0.004	0.1513	0.0014	0.792	0.003	0.3788	0.0045	0.3261	0.0027
870	0.310	0.00411	0.00033	0.00359	0.00021	0.0764	0.0020	1.039	0.009	0.1611	0.0020	0.815	0.006	0.3828	0.0047	0.3227	0.0023
1260	0.969	0.00532	0.00017	0.00375	0.00018	0.0843	0.0008	1.085	0.004	0.1616	0.0011	0.812	0.004	0.3851	0.0024	0.3219	0.0026
1500	0.790	0.00485	0.00016	0.00442	0.00024	0.0835	0.0006	1.046	0.005	0.1624	0.0014	0.834	0.004	0.3797	0.0027	0.3182	0.0024
1610	0.021	0.00461	0.00115	0.00372	0.00119	0.0757	0.0043	1.030	0.029	0.1656	0.0084	0.804	0.026	0.3912	0.0157	0.3353	0.0139
1770	0.014	0.00495	0.00101	0.00432	0.00139	0.0738	0.0067	1.025	0.036	0.1585	0.0112	0.823	0.024	0.3749	0.0149	0.3455	0.0212
Total	3.150	0.00443	0.00009	0.00371	0.00010	0.0792	0.0005	1.050	0.002	0.1583	0.0007	0.811	0.002	0.3806	0.0018	0.3226	0.0013
1260+1500°C	1.759	0.00511	0.00012	0.00405	0.00015	0.0840	0.0005	1.067	0.003	0.1619	0.0009	0.822	0.003	0.3816	0.0018	0.3202	0.0018

A0105-04 (173 µg)

340	0.155	0.00310	0.00025	0.00343	0.00029	0.0688	0.0044	0.986	0.008	0.1494	0.0028	0.7925	0.0067	0.3862	0.0046	0.3243	0.0047
530	0.391	0.00388	0.00014	0.00317	0.00012	0.0730	0.0009	0.993	0.004	0.1507	0.0011	0.7900	0.0046	0.3862	0.0023	0.3272	0.0025
700	0.099	0.00395	0.00026	0.00370	0.00037	0.0755	0.0015	1.065	0.009	0.1536	0.0026	0.8061	0.0140	0.3857	0.0047	0.3287	0.0042
870	0.217	0.00419	0.00023	0.00392	0.00026	0.0777	0.0014	1.090	0.009	0.1597	0.0024	0.8223	0.0057	0.3865	0.0044	0.3282	0.0029
1000	0.377	0.00529	0.00024	0.00417	0.00020	0.0835	0.0009	1.157	0.006	0.1596	0.0011	0.8237	0.0043	0.3837	0.0028	0.3253	0.0026
1130	0.278	0.00452	0.00021	0.00420	0.00022	0.0848	0.0013	1.108	0.005	0.1630	0.0020	0.8195	0.0048	0.3770	0.0026	0.3131	0.0021
1260	0.191	0.00491	0.00022	0.00402	0.00021	0.0844	0.0024	1.054	0.006	0.1633	0.0017	0.8289	0.0057	0.3828	0.0037	0.3168	0.0028
1400	0.311	0.00468	0.00016	0.00432	0.00017	0.0824	0.0017	1.034	0.003	0.1659	0.0016	0.8184	0.0044	0.3809	0.0026	0.3196	0.0027
1500	0.287	0.00513	0.00015	0.00414	0.00021	0.0805	0.0023	1.051	0.005	0.1654	0.0019	0.8128	0.0066	0.3775	0.0027	0.3180	0.0027
1610	0.006	0.00361	0.00121	0.00338	0.00083	0.0791	0.0143	1.083	0.031	0.1555	0.0066	0.8568	0.0348	0.3809	0.0262	0.3501	0.0187
1770	0.004	0.00354	0.00078	0.00403	0.00168	0.0834	0.0062	0.993	0.044	0.1522	0.0095	0.8576	0.0365	0.3682	0.0274	0.3444	0.0212
Total	2.323	0.00452	0.00007	0.00401	0.00007	0.0791	0.0006	1.065	0.002	0.1600	0.0006	0.8131	0.0019	0.3827	0.0010	0.3216	0.0010
1000-1500°C	1.444	0.00493	0.00009	0.00418	0.00009	0.0830	0.0008	1.086	0.002	0.1633	0.0007	0.8203	0.0002	0.3818	0.0013	0.3191	0.0012

Reference compositions

Component (reference)	¹²⁴ Xe	± (1σ)	¹²⁶ Xe	± (1σ)	¹²⁸ Xe	± (1σ)	¹²⁹ Xe	± (1σ)	¹³⁰ Xe	± (1σ)	¹³¹ Xe	± (1σ)	¹³⁴ Xe	± (1σ)	¹³⁶ Xe	± (1σ)
Q (S1)	0.00455	0.00002	0.00406	0.00002	0.0822	0.0002	1.042	0.002	0.1619	0.0003	0.8185	0.0009	0.3780	0.0011	0.3164	0.0008
HL (S2)	0.00839	0.00009	0.00534	0.00008	0.0905	0.0006	1.056	0.002	0.1542	0.0003	0.8457	0.0013	0.6356	0.0013	≅0.6991	
SW (S12)	0.00395	0.00026	0.00370	0.00037	0.0755	0.0015	1.065	0.009	0.1536	0.0026	0.8061	0.0140	0.3857	0.0047	0.3287	0.0042
G (S13)	≅ 0		≅ 0		0.2159	0.0023	0.1182	0.0112	0.4826	0.0042	0.1858	0.0117	0.0222	0.0053	≅0.0034	
Earth atmosphere (S10)	0.3537	0.0011	0.3300	0.0017	7.136	0.009	0.9832	0.0012	.15136	.00012	0.7890	0.0011	0.3879	0.0006	0.3294	0.0004
²³⁸ U fission (S11)	0		0		0		<0.003		0		0.128	0.005	1.398	0.020	1.681	0.048
²⁴⁴ Pu fission (S13)	0		0		0		0.054	0.062	0		0.278	0.017	1.041	0.006	1.120	0.016

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